FAULT EVALUATION REPORT FER-157

HARTLEY SPRINGS FAULT ZONE, MONO COUNTY

by

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INTRODUCTION

Potentially active faults located in south-central Mono County evaluated in this FER include the Hartley Springs fault zone and the Silver Lake fault zone (figure 1). The Western Long Valley/June Lake study area is located in the Devils Postpile and Mono Craters 15-minute quadrangles. These faults are evaluated as part of a statewide effort to evaluate faults for recency of activity. Those faults determined to be sufficiently active and well defined are zoned by the State Geologist as directed by the Alquist-Priolo Special Studies Zones Act (Hart, 1980).

SUMMARY OF AVAILABLE DATA

The Western Long Valley/June Lake study area is characterized by Basin and Range style normal faulting. However, late Holocene volcanic activity within and north of Long Valley caldera has complicated structural relationships and locally obscures evidence of recent faulting.

Topography in the study area is varied. Rugged, alpine glaciated peaks are located west of June Lake and contrast with the lower, relatively flat area just north of June Lake. Mountains of moderate to rugged relief characterize the majority of the study area south of June Lake.

Predominant rock types in the study area can be divided into three general categories. Mesozoic plutonic basement rocks with associated Paleozoic roof pendant rocks generally crop out west of the major fault zones. Abundant volcanic rocks ranging in age from late Cenozoic to late Holocene occur throughout most of the study area. Pleistocene glacial deposits generally associated with the Sherwin, Tahoe, Tenaya, and Tioga glacial stages are abundant in the June Lake area and occur less frequently south of June Lake. Principal references for the geology of the study area include Strand (1967), Kistler (1966a), Huber and Rinehart (1965), Bailey (1974), and Bailey and Koeppen (1977).

Development in the study area is very sparse. The town of Mammoth Lakes is growing very rapidly but is only beginning to encroach in the southeastern part of the study area, mainly with resort homes. Development in the June Lake area generally is limited to resort homes, boat launch facilities, and campgrounds. Logging has occurred to some degree throughout the study area. However, land surfaces mostly have not been altered by man.

HARTLEY SPRINGS FAULT ZONE

The Hartley Springs fault zone is a major Sierra Nevada range-front fault (Bailey, et al., 1976) (figure 1). Displacement along the fault is normal, down to the east. Topographic relief across the escarpment is about 2,000 feet (Bailey, et al., 1976). The Hartley Springs fault zone vertically offsets Tertiary volcanic rocks by about 1,500 feet and Pleistocene Bishop Tuff by about 1,000 feet (Bailey, et al., 1976). The Hartley Springs fault zone extends south into Long Valley caldera, where individual strands offset trachyandesite (0.08 my to 0.2 my old) by about 50 feet, rhyolite ($\simeq$0.1 my old) by about 33 feet and 650 yr old phreatic deposits by about 16 feet (Bailey, et al., 1976).

Traces of the Hartley Springs fault zone have been mapped by Huber and Rinehart (1965), Kistler (1966a), Envicom (1976), and Bailey and Koeppen (1977) (figure 2). Traces mapped by Huber and Rinehart were incorporated into the mapping of Bailey and Koeppen and are not shown on figure 2.

Mapping by Bailey and Koeppen (1977) is the most detailed along the Hartley Springs fault zone (figure 2). Bailey and Koeppen mapped an essentially north-trending, complex zone of normal faults. Within Long Valley caldera, Holocene air fall pumice deposits are offset by segments of the Hartley Springs fault zone (figure 2). South of Deer Mountain, phreatic deposits considered to be about 650 yrs. old (Rinehart and Huber, 1965; Bailey and Koeppen, 1977) are offset along segments of the Hartley Springs fault zone (figure 2). North of Long Valley caldera, Holocene pumice deposits are offset in Section 5, T3S, R27E and Sections 7, 18, 19, T2S, R27E (figure 2). Holocene pumice deposits are not offset in Sections 20, 29, and 32, T2S, R27E (Bailey and Koeppen, 1977) (figure 2).

Envicom (1976) mapped concealed and approximately located traces of the Hartley Springs fault zone (which they term the Inyo Craters fault zone) that only locally correspond to faults mapped by Bailey and Koeppen (1977). Envicom mapped faulted pumice in Section 32, T2S, R27E (Bailey and Koeppen, 1977, map the fault as concealed by Holocene pumice), and mapped a Tioga-stage moraine as possibly offset by a segment of the Hartley Springs fault (figure 2). Envicom considers segments of the Hartley Springs fault zone to be active (i.e. Holocene).

Kistler (1966a) mapped short, northwest-trending segments of the Hartley Springs fault zone in the southeast quarter of the Mono Craters quadrangle (figure 2). Kistler generally mapped the Hartley Springs fault as concealed by Bishop Tuff. However, Kistler (1966b) states that the Hartley Springs fault has vertically offset the Bishop Tuff about 300 feet. A concealed fault trace in Sections 18, 19, and 20, T2S, R27E, generally corresponds with faults mapped by Envicom (1976) and Bailey and Koeppen (1977) (figure 2).

The Hartley Springs fault zone is unique in that both of its far ends pass into relatively young volcanic features and significant portions of its main trace have been partly obscured by the extrusion of very young ($\lesssim$1,000 yrs. BP) rhyolite domes (Bailey and Koeppen, 1977). At its southern end, the Hartley Springs fault zone passes into Long Valley caldera. Like the Hilton Creek fault to the southeast, cumulative vertical displacement is significantly less inside the caldera than outside the caldera. To the north, the Hartley Springs fault zone passes into the Mono Craters ring fracture system (figure 1) (Kistler, 1966b). Offset is very distributive and is much less in magnitude within this ring-fracture area, and may be analogous to faults within the Long Valley caldera.

Earthquakes that occurred in the Mammoth Lakes area during May 1980 produced surface rupture along segments of the Hartley Springs fault zone within Long Valley caldera, east of the study area (Taylor and Bryant, 1980). Hairline cracks were observed along the "earthquake fault" in the Mt. Morrison quadrangle (Taylor and Bryant, 1980) and parts of the "earthquake fault" were recommended for zoning for special studies (Bryant, 1981). Parts of the "earthquake fault" extend into this study area (figure 2). Extension cracks were observed by this writer in July 1980 along parts of the Dry Creek segment of the Hartley Springs fault (figure 3, locality 3, Table 1) (Taylor and Bryant, 1980). Although faulting cannot be ruled out, it seems possible that the cracking was secondary and probably related to shaking.

SILVER LAKE FAULT ZONE

The Silver Lake fault zone, a north northwest-trending normal fault, is a major range-front fault. The Silver Lake fault displaces Sherwin glacial deposits ($>$ 700,000 yrs old) by about 1,000 feet, down to the east (Kistler, 1966b). Mapping by Kistler (1966a) depicts an approximately located fault offsetting Tahoe glacial deposits but not younger Tioga deposits (figure 2). The Silver Lake fault mapped by Kistler (1966a) is essentially the same trace mapped by Envicom (1976). Envicom (1976) states that there is no evidence for Holocene activity along the Silver Lake fault. Tioga glacial deposits are not offset and evidence of faulted Tahoe glacial deposits is poor.

Clark, et al., (1983) indicate that a Tahoe lateral moraine is offset along the Silver Lake fault just north of Parker Lake (figure 2). However, they concluded that Tioga lateral moraines are not offset along this fault. Bailey and Koeppen (1977) mapped two subparallel faults that will be termed the western and eastern Silver Lake fault zone (figure 2). The western Silver Lake fault is similar in trend and location to the fault mapped by Kistler (1966a) (figure 2). However, Bailey and Koeppen mapped the fault as concealed by all deposits except bedrock. The eastern Silver Lake fault zone is more complex (figure 2). Bailey and Koeppen mapped Holocene colluvium as offset in Section 18, T3S, R27E (figure 2). Near the northern end of the eastern Silver Lake fault, Tioga glacial deposits are offset (Bailey and Koeppen, 1977) (figure 2).

INTERPRETATION OF AERIAL PHOTOGRAPHS AND FIELD OBSERVATIONS

Significant observations based on both air photo interpretation and field observations by this writer, and mapping by others, are summarized in Table 1. Locality numbers identified on figures 2 and 3 refer to specific data relative to fault recency, degree of definition (i.e., well defined or poorly defined), ages of deposits that are offset or that conceal faults, and additional pertinent information. Table 1, in conjunction with figures 2 and 3, contains the majority of supporting data relevant to zoning decisions. Air photo interpetation by this writer of faults in the Western Long Valley/June Lake study area was accomplished using U.S. Forest Service air photos (IN04, 1977, 1:15,840 scale).

Approximately two days were spent in the Western Long Valley/June Lake study area during November 1983 by this writer in order to verify selected faults interpreted from air photos. Subtle features not observable on the air photos also were mapped in the field. Results of air photo interpretation and field observations by this writer are summarized on figure 3.

An attempt was made to measure fault scarp profiles in order to estimate recency of faulting based on the work of Wallace (1977). Points of observation and locations where fault scarp profiles were measured are shown on figure 3 and are summarized in Table 2. It should be emphasized that these measurements represent only approximations of scarp height, angle, and width of scarp crest. Scarp height was measured using the method described by Lahee (1961, p. 454). Scarp angle was estimated by using a Bunton compass clinometer and an improvised leveling rod, as described by Wallace (1977). The width of the scarp's crest was estimated by pacing.

A direct correlation between the ages indicated by fault scarp profiles measured by Wallace (1977) in Nevada and scarp profiles measured during investigations for this FER cannot be made due to different lithology, climate, and styles of faulting (Mayer, 1982). However, the data presented by Wallace (1977, 1978) can be used as a guide (or additional factor) when evaluating the geomorphic features and age of offset deposits (when known) for recency of faulting. Some very general guidelines for estimating scarp ages are summarized as follows: minimum fault scarp angles for faults in unconsolidated alluvium and colluvium no older than 10,000 to 12,000 yrs. BP can range from 10° to 20° (Wallace, 1977). The average scarp angle is about 14° to 15°, based on figure 8 of Wallace (1977), although figure 12 of Wallace (1977) indicates that scarp angles of about 19° represent minimum Holocene age. The scarp crest width for scarps no older than about 10,000 yrs. BP range from 3.2 to about 16 feet (figure 11 from Wallace, 1977). Wide variations occur, but these figures probably represent minimum (i.e. conservative) criteria suggesting Holocene ages. The Western Long Valley/June Lake study area is generally wetter than Wallace's Nevada study region and is probably subject to more rapid degradation of the geomorphic features. In addition, very young ($\lesssim$ 1,000 yrs. BP) volcanic events have deposited pyroclastic units that locally may drape across scarps, modifying original scarp profiles.

HARTLEY SPRINGS FAULT ZONE

Segments of the Hartley Springs fault zone within Long Valley caldera are generally very well defined and are characterized by geomorphic features indicating Holocene faulting, based on air photo interpretation and field checking by this writer (figure 3, Table 1). Fault traces mapped by Bailey and Koeppen (1977) generally were verified by this writer north of Mammoth Mountain (figures 2, 3). The Mammoth Mountain and McCloud Lake segments mapped by Bailey and Koeppen (1977) are not as well defined and geomorphic evidence of recent activity was not observed by this writer (figure 2, Table 1).

North of Long Valley caldera, the Hartley Springs fault zone is comparatively less well defined (figure 3). However, very young rhyolite domes ($\lesssim$ 1,000 yrs. BP, Bailey and Koeppen, 1977) were extruded along the principal trace of the Hartley Springs fault zone. These domes, and the air fall pumice deposits that immediately preceded dome implacement, may obscure or conceal ephemeral geomorphic features indicating Holocene faulting (figure 3). Relatively short fault-segments west of the main trace of the Hartley Springs fault zone are locally well defined (localities 7, 8; figure 3, Table 1).

In the June Lake area, the Hartley Springs fault zone is characterized by discontinuous fault segments that are only locally well defined (figure 3). Fault traces mapped by Bailey and Koeppen (1977) were only locally verified by this writer (figures 2, 3, Table 1).

Slip rates along the Hartley Springs fault zone vary significantly, probably reflecting: (1) slip rates varying through time, (2) different fault segments rupturing at different points in time, and (3) locally, effects of volcanic/magmatic adjustments interacting with tectonics. Clark, et al. (1983) calculated a preferred slip rate of 0.15 mm/yr. along a fault segment north of Reversed Peak (locality 13, figure 3, Table 1). Bailey, et al., (1976) reported that the Hartley Springs fault offsets Pliocene volcanic rocks about 450m, yielding a slip rate between 0.14 to 0.17 mm/yr. Bishop Tuff is offset about 300m, yielding a slip rate of about 0.42 mm/yr. Very recent phreatic deposits ($\cong$ 650 yrs. old) are offset about 5m (Bailey, et al., 1976), yielding a slip rate of about 7.5 mm/yr. It is quite likely that the offset phreatic deposits are nearly contemporaneous with the formation of Inyo Craters and the offset may be entirely of volcanic origin for the Deer Mountain segment of the Hartley Springs fault zone (as compared with offset that is mainly tectonic for the fault zone north of Long Valley caldera to June Lake).

SILVER LAKE FAULT ZONE

The western branch of the Silver Lake fault zone is fairly well defined from near Fern Lake northwest to the southern part of Section 8, T2S, R26E (figure 3). Just west of Silver Lake, the fault is delineated by a well-defined, east-facing scarp in bedrock (locality 17, Table 1, figure 3). Specific, ephemeral geomorphic features indicating Holocene faulting were not observed by this writer. However, there is a definite break-in-slope at the base of the bedrock slope.

Northwest of this location, the fault is less well defined and is obscured or concealed by Holocene talus deposits (figure 2). Tioga lateral moraines of Parker Lake clearly are not offset, indicating a lack of activity for the northern end of the fault since Tioga time (13,000 yrs. BP). Elsewhere, Tioga and younger deposits did not seem to be offset, based on air photo interpretation by this writer (figure 2, locality 17, Table 1).

The eastern Silver Lake fault zone of Bailey and Koeppen (1977) is not well defined south of Reversed Creek in the June Lake area (figure 2). Faults mapped by Bailey and Koeppen (1977) just east of Silver Lake generally are not well defined and may be gravitational creep or lateral spread features (locality 18, figure 2, Table 1). A short, north-trending fault which forms the west side of a well-defined graben north of Rush Creek offsets a lateral moraine that is probably Tioga age (locality 19, figure 2, Table 1). The fault cannot be readily followed south of Rush Creek, although a linear trough in the NW-1/4 Section 9, T2S, R26E may delineate the southern continuation of this fault.

Clark, et al. (1983) calculated a preferred slip rate of 0.5 mm/yr. along the Silver Lake fault, based on the offset Tahoe moraine at Parker Lake (figure 2). Kistler (1966b) estimates that about 1,000 feet of post-Sherwin, pre-Tahoe displacement has occurred along the Silver Lake fault. Assuming that Sherwin glacial deposits are older than 700,000 yrs., a late Quaternary slip rate of about 0.4 mm/yr. has occurred along the Silver Lake fault zone.

SEISMICITY

No well-defined zone of seismicity is associated with the Hartley Springs fault zone (Real, et al., 1978). A single M = 3.0-3.9 earthquake is located just east of the fault near the intersection of Highway 395 and the road to June Lake (Section 6, T2S, R27E). Recent seismicity near Mammoth Lakes has resulted in detailed seismic monitoring of the area. However, the Hartley Springs fault zone currently remains seismically quiescent (C. Cramer, p.c., January 1984; R. Cockerham, Seminar on Seismicity near Mammoth Lakes given November 17, 1983; M. Somerville, seminar on historic seismicity of Mammoth Lakes region given January 4, 1984).

CONCLUSIONS

HARTLEY SPRINGS FAULT ZONE

The Hartley Springs fault zone is a major range front fault with down-to-the-east normal displacement (Bailey, et al., 1976). The fault zone is generally well defined in Long Valley caldera, offsets Holocene deposits (Bailey and Koeppen, 1977), and is characterized by geomorphic features characteristic of Holocene faulting (figure 3, Table 1). The Hartley Springs fault zone is less well defined north of Long Valley caldera and is distributive in the June Lake area. However, specific segments of the Hartley Springs fault zone north of Long Valley caldera are well defined. Very recent volcanic activity of Inyo Craters and Mono Craters may have obscured ephemeral geomorphic evidence of Holocene faulting. The Inyo Craters (rhyolite domes with associated pyroclastic deposits) have erupted along the principal trace of the Hartley Springs fault zone. The lack of specific geomorphic features along this segment of the Hartley Springs fault zone does not necessarily preclude the hazard of future surface fault rupture.

Fault traces mapped by Bailey and Koeppen (1977) were generally verified by this writer in Long Valley caldera. Faults north of Long Valley caldera and in the June Lake area generally are less well defined and were only locally verified by this writer (figure 3).

SILVER LAKE FAULT ZONE

The Silver Lake fault zone is a major, down-to-the-east normal fault zone. The western Silver Lake fault mapped by Bailey and Koeppen (1977) is generally well defined in bedrock from near Silver Lake south to Fern Lake. Tahoe glacial deposits are offset along this fault segment, but ephemeral geomorphic features characteristic of Holocene normal faulting were not observed by this writer. To the north, the fault is less well defined. At Parker Lake, Tahoe glacial deposits are offset, but Tioga lateral moraines clearly are not offset (Clark, et al., 1983; Bryant, this report, figure 2).

The eastern Silver Lake fault zone in the June Lake area mapped by Bailey and Koeppen (1977) may, in fact, be primarily lateral spreading features, especially just east of Silver Lake (locality 18, figure 2). About 4-1/2 miles south of Reversed Creek, the eastern Silver Lake fault offsets possible Holocene deposits (locality 16, figure 2). However, air photo coverage was not available to this writer south of Yost Lake. The area along the eastern Silver Lake fault zone south of Reversed Creek is relatively remote and no further evaluation is anticipated.

Slip rates along the Silver Lake fault zone (0.5 mm/yr. - Clark, et al., 1983; 0.4 mm/yr., Kistler, 1966b) are considerably higher than calculated slip rates for the Hartley Springs fault zone (0.14 mm/yr. to 0.4 mm/yr. - Clark, et al., 1983; Bailey, et al., 1976). This suggests that the Silver Lake fault zone may have been more active during Pleistocene time in the past, but the lack of clear geomorphic evidence of Holocene faulting and the lack of offset of latest Pleistocene glacial deposits argues against Holocene activity along most of the Silver Lake fault zone.

RECOMMENDATIONS

Recommendations for zoning faults for special studies are based on the criteria of "sufficiently active" and "well-defined" (Hart, 1980).

HARTLEY SPRINGS FAULT ZONE

Zone for special studies well-defined traces of the Hartley Springs fault zone shown on figure 4. Principal references cited should be Bailey and Koeppen (1977) and this FER.

SILVER LAKE FAULT ZONE

Zone for special studies well-defined traces of the Silver Lake fault zone shown on figure 4. Principal references cited should be Bailey and Koeppen (1977) and this FER.

Reviewed; recommendations approved. Earl W. Hart CEG 935 3/16/84

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Table 1 (to FER-157). Locality descriptions listing selected data pertinent to fault recency, based on air photo interpretation and field observations by Bryant (this report). Additional data pertinent to fault recency are based on the work of others.

Locality #	Fault Name	Geomorphic Feature Delineating fault	Fault Well Defined(?)	Youngest Unit Offset and Source	Oldest Unit Not Offset & Source	Remarks[1]
1 (fig. 3)	Hartley Springs f.z.-Minaret Summit segment	scarp; graben	Yes	Holocene pumice(Bailey and Koeppen, 1977)	N/A	Well-defined scarp; h=25', $\measuredangle$=30°, c $\simeq$ 10'. Some logging has occurred in the area; flt. not well-defined south of road and trace of Bailey and Koeppen (1977) could not be verified. Many trees are tilted along scarp, suggesting recent activity. However, very young trees ($<$ 10yrs.old) are also tilted, indicating that downhill creep is cause. North of this locality a well-defined graben characterizes fault.
2 (fig. 3)	Hartley Springs f.z.-Dry Creek segment	scarp; dov, small graben	Yes	Holocene pumice (Bailey and Koeppen, 1977)	N/A	Fault very well defined. Dry Creek is deflected along this fault segment; stream erosion may enhance some segments of the fault
3 (fig. 3)	Hartley Springs f.z.-Dry Creek segment	scarp; dov	Yes	Pleistocene dacite (Bailey and Koeppen, 1977)	N/A	Steeply east-dipping fault plane exposed in dacite bedrock. Striations indicate predominantly vertical offset with very minor component of right-lateral strike-slip displacement. To south of this location, extension cracks observed along fault following May 1980 Mammoth Lakes EQ (Taylor and Bryant, 1980). Cracks were probably due to shaking rather than surface rupture, although minor faulting cannot be ruled out.

1 Unless otherwise noted, all observations by Bryant (this report), based on air photo interpretation and field checking. Field observations indicated on figures 2, 3. Refer to figure 3 for symbol explanations.

Table 1 (to FER-157)

Locality Descriptions

Locality #	Fault Name	Geomorphic Feature Delin-eating fault	Fault Well Defined(?)	Youngest Unit Offset and Source	Oldest Unit Not Offset & Source	Remarks[1]
4 (fig. 3)	Hartley Springs f.z.-Deer Mountain segment	scarp	Yes	Holocene phre-atic deposits (650yrs. BP) (Bailey and Koeppen, 1977)	N/A	Well-defined E-facing scarp offsets rim of southern Inyo Crater. Trachyandesite exposed in crater wall is offset, down to the east and is consistent with displace-ment indicated by scarp. Scarp profile(located about 300' south of crater)h=35', $\measuredangle$=30^o, c$\simeq$3-5'. Height of scarp and 15-foot displacement of phreatic deposits indicated by Bailey, et al. (1976) suggest that stream erosion has enhanced scarp at this location.
5 (fig. 3)	Hartley Springs f.z.-Deadman Creek segment	scarp	partly	Holocene pumice (Bailey and Koeppen, 1977)	Holocene pumice and alluvium (Bailey & Koeppen, 1977)	Fault is very short and cannot be followed to north and south. How-ever, geomorphic evidence is obscured by very young rhyolite domes on the order of $\simeq$ 1000yrs. old.
6 (fig.2,3)	Hartley Springs f.z.	scarp	partly	Triassic bed-rock (Bailey & Koeppen, 1977)	Holocene talus & rhyolite dome (Bailey & Koeppen, 1977)	Specific geomorphic features not observed; generally obscured by talus & extrusion of very young rhyolite dome. General location of fault suggested by E-facing escarpment.

Table 1 (to FER-157)

Locality Descriptions

Locality #	Fault Name	Geomorphic Feature Delineating fault	Fault Well Defined(?)	Youngest Unit Offset and Source	Oldest Unit Not Offset & Source	Remarks[1]
7 (fig. 3)	Hartley Springs f.z.	scarp; cd; pa; dd; tr; vertically offset ridge	mostly	Pleistocene (700,000yrs.) Bishop tuff (Bailey and Koeppen, 1977)	N/A	Fault segment characterized by w-facing scarp in granitic bedrock. Ponded alluvium and deflected drainage suggest youthfulness, but may be partly erosional. However, the closed depression and vertically offset ridge (down to the west) indicate recent faulting. Bishop tuff(Bailey & Koeppen, 1977) offset just north of cd.
8 (fig. 3)	Hartley Springs f.z.	scarp; dov; bd(?)	Yes	Holocene alluvium, colluvium (Bailey and Koeppen, 1977)	N/A	Well defined, youthful scarps, vertically offset drainage, and offset stream deposits indicate Holocene activity.
9 (fig. 3)	Hartley Springs f.z.	scarp; knickpoint in drainage	partly	Holocene pumice deposits and 700,000yr.old Bishop tuff (Bailey and Koeppen, 1977)	N/A	W-facing scarp is subtle and partly eroded-scarp profile h=11', $\measuredangle = 12^\circ$, c $>$ 25'. E-facing scarp is main trace of Hartley Springs fault zone. This area has been modified by logging.
10 (fig.2,3)	Hartley Springs f.z.	NE-facing escarpment	No	700,000 yrs.old Bishop tuff (Bailey and Koeppen, 1977)	Tahoe-stage lateral moraine (Bailey & Koeppen, 1977)	General NE-facing escarpment indicates fault location, but evidence of recent activity lacking.

Table 1 (to FER-157)

Locality Descriptions

Locality #	Fault Name	Geomorphic Feature Delineating fault	Fault Well Defined(?)	Youngest Unit Offset and Source	Oldest Unit Not Offset & Source	Remarks[1]
11 (fig. 3)	Hartley Springs f.z.	scarp	partly	Tioga-stage glacial deposits (Bailey and Koeppen, 1977)	N/A	Subtle scarp in Tioga glacial deposits-scarp profile h=12', $\measuredangle$=12°, c-very rounded. Fault segment is short and cannot be followed to S, where Tahoe lateral moraine is not offset. Glacial deposits probably outwash-coarse sand, some gravel-relatively cohesionless.
12 (fig. 3)	Hartley Springs f.z.	scarp; cd(?)	partly	Tioga glacial deposits (Bailey & Koeppen, 1977)	N/A	W-facing scarp offsets Bishop tuff against Tioga glacial deposits. Scarp offsetting Tahoe moraine-profile h=15', $\measuredangle$ = 20°, c$\cong$20'. Scarp diminishes to north, has $\measuredangle$ = 6°
13 (fig.3)	Hartley Springs f.z.-Reversed Peak segment	scarp; dov	mostly	Tioga lateral moraine (Bailey & Koeppen, 1977; Clark, et al., 1983)	Holocene colluvium (Bryant, this report)	Well-defined scarp offsets Tahoe lateral moraine-scarp profile h $>$50', $\measuredangle$=30°, c $\cong$ 10'-15'. Tioga lateral moraine offset to the north-scarp profile h=12', $\measuredangle$=16°, c rounded. Colluvium deposited over scarp.

Table 1 (to FER-157)

Locality Descriptions

Locality #	Fault Name	Geomorphic Feature Delineating fault	Fault Well Defined(?)	Youngest Unit Offset and Source	Oldest Unit Not Offset & Source	Remarks[1]
14 (fig. 2)	Hartley Springs f.z.-McCloud Lake segment	subtle escarpment	No	Holocene talus deposits (Bailey and Koeppen, 1977)	N/A	Bryant (this report) could not verify offset talus mapped by Bailey & Koeppen (1977), based on field observations. B & K mapped a W-facing scarp-this feature is not well-defined. A prominent E-facing escarpment to E of McCloud Lake is probably erosional along prominent NNE-trending, near vertical joints.
15 (fig. 2)	Hartley Springs f.z.-Mammoth Mountain segment	t and v.c.	No	Holocene colluvium (Bailey & Koeppen, 1977)	Holocene talus (Bryant, this report)	NE-facing (back-facing) scarp mapped by Bailey & Koeppen (1977). Scarp not well-defined-flt. delineated by t & v.c.-scarp probably has been buried by Holocene talus deposits--no evidence of offset colluvium, except for a short segment characterized by a tonal lineament in colluvium(?).
16 (fig. 2)	E. branch Silver Lake flt. zone	N/A	N/A	Holocene colluvium offset? (Bailey & Koeppen, 1977)	Undifferentiated glacial deposits (Pleistocene) (Bailey & Koeppen, 1977)	Air photo coverage not available to this writer along most of this segment. Bailey and Koeppen (1977) map late Quaternary (Holocene?)colluvium locally offset along this fault and locally to conceal the fault. Holocene pumice desposits not offset along southern end of fault and undifferentiated glacial deposits (Pleistocene) not offset just north of this locality.

Table 1 (to FER-157)

Locality Descriptions

Locality #	Fault Name	Geomorphic Feature Delineating fault	Fault Well Defined(?)	Youngest Unit Offset and Source	Oldest Unit Not Offset & Source	Remarks[1]
17(fig. 2,3)	West branch Silver Lake fault zone	General E-facing escarpment	partly	Holocene talus deposits(Bailey & Koeppen, 1977) Tahoe lateral moraine (Clark, et al., 1983)	Tioga lateral moraine (Bailey & Koeppen, 1977)	Faulted bedrock-DePolo (1982) considers this flt.(which he terms the Dana Plateau flt.)to be a portion of the Sierra Nevada fault zone. However, he states that: (1)the youngest deposits offset along this fault are glacial deposits of Sherwin (> 700,000yrs) age;(2)the fault scarp is highly eroded;(3)the fault lacks seismicity. This writer could not verify the Holocene talus deposits mapped as offset by Bailey & Koeppen (1977)near Fern Lake. A linear contact between granitic bedrock and talus along the west side of Silver Lake could be erosional because this area has been modified by glacial erosion. However, the linear contact at the base of the slope is sharp, near vertical, and is probably related to either jointing or faulting. Glacial deposits (Tahoe mapped by Kistler, 1966a) are vertically offset along this east-facing escarpment about 1,500 feet north of Fern Lake, indicating that escarpment is fault-related. The fault generally is well defined from Fern Lake northwest to the northern half of Section 17, T2S, R26E. Clark et al. (1983) observed an offset Tahoe lateral moraine along this fault just north of Parker Lake. However, a Tioga lateral moraine crosses this fault and is not offset (Clark, et al., 1983; Bryant, this report).

Table 1 (to FER-157)

Locality Descriptions

Locality #	Fault Name	Geomorphic Feature Delineating fault	Fault Well Defined(?)	Youngest Unit Offset and Source	Oldest Unit Not Offset & Source	Remarks[1]
18 (fig. 2)	E. branch of Silver Lake fault zone	general escarpments, ld.	Partly	Tioga glacial deposits(Bailey & Koeppen, 1977)	N/A	Three north to northwest-trending faults mapped by Bailey & Koeppen (1977) were not completely verified by this writer. Several closed depressions occur at the top of the ridge, and many back-facing (east-facing) scarps and sidehill troughs were observed by this writer. Prominent jointing or foliation planes in metamorphic bedrock coincide with the general trend of faults mapped by Bailey and Koeppen. The steep-sided canyon just west of these features (which was occupied by Tahoe and Tioga stage glaciers), the sidehill troughs along near vertical planes of weakness, and hilltop closed depressions all strongly indicate that gravity creep or "sackung" (Radbruch-Hall, et al., 1977; Beck, 1968) has occurred at this location, rather than, or perhaps in addition to, tectonic faulting.
19 (fig. 2)	E. branch of Silver Lake fault zone	scarp, s; graben	partly	Tioga glacial deposits(Bailey & Koeppen, 1977)	N/A	Western fault segment generally well defined; vertically offsets Tioga lateral moraine. However, fault segment is short and cannot be followed to north or south. Tioga lateral moraine seems to be draped across faulted bedrock along eastern fault, perhaps indicating that gravitational creep, rather than faulting has displaced the moraine.

Table 1 (to FER-157)

Locality Descriptions

Locality #	Fault Name	Geomorphic Feature Delin-eating fault	Fault Well Defined(?)	Youngest Unit Offset and Source	Oldest Unit Not Offset & Source	Remarks[1]
20 (fig. 2)	E. branch of Silver Lake fault zone	scarp, t	partly	Tioga glacial deposits(Bailey & Koeppen, 1977)	N/A	Queried fault mapped by Bailey and Koeppen(1977). E-facing scarp and t in Sherwin glacial deposits, no evidence of offset of Tahoe or Tioga deposits.
21(fig. 2,3)	Hartley Springs f.z.	scarp	mostly	Tioga glacial deposits(Bailey & Koeppen, 1977)	N/A	North to northwest-trending zone of discontinuous faults mapped by Bailey & Koeppen (1977). Well defined faults that coincide or could be verified by Bryant (this report) are shown on figure 3 (also see locality #12).

Table 2 (FER 157)

Fault Scarp Profiles

Fault Name	Height	Slope Angle	Crest Width	Material Offset	Fault Type
Hartley Springs Flt.					
Minaret Summit seg. Sec. 30, T3S, R27E	25'	30°	≈ 10'	Holocene pumice	normal
Minaret Summit seg. Sec. 30, T3S, R27E (same fault)	25'	26°	≈ 8'	Holocene pumice	normal-- W. side of graben
Minaret Summit seg. Sec. 30, T3S, R27E (same fault)	6'	25°	≈ 10'	Holocene pumice	normal-- E. side of graben
Deer Mountain seg. Sec. 17, T3S, R27E	35'	30°	3'-5'	Holocene phreatic deposits(650 yrs.)	normal
Deer Mountain seg. Sec. 17, T3S, R27E	55'	35°	2'-3'	Holocene phreatic deposits and late Pleistocene andesite	normal
Deer Mountain seg. Sec. 16, T3S, R27E	15'	26°	10'	Holocene phreatic deposits	normal
Deadman Creek seg. Sec. 5, T3S, R27E	15'	26°	10'	Holocene(?) terrace deposits	normal
Hartley Springs f.z. Sec. 18, T2S, R27E	11'	12°	> 25'	Pleistocene Bishop tuff and Holocene pumice deposits	normal-- back facing scarp
Hartley Springs f.z. Sec. 1, T2S, R26E	12'	12°	rounded	Tioga glacial deposits	normal
Hartley Springs f.z. Sec. 36, T1S, R26E	≈ 5'	10°-12°	NM	Tioga glacial deposits	both sides of graben, or large fissure(?)
Hartley Springs f.z. Sec. 26, T1S, R26E	15'	20°	20'	Tenaya(?) lateral moraine	normal
Reversed Peak seg. Sec. 34, T1S, R26E	> 50'	30°	10'-15'	Tahoe lateral moraine	normal
Reversed Peak seg. Sec. 34, T1S, R26E (same fault)	12'	16°	rounded	Tioga lateral moraine	normal

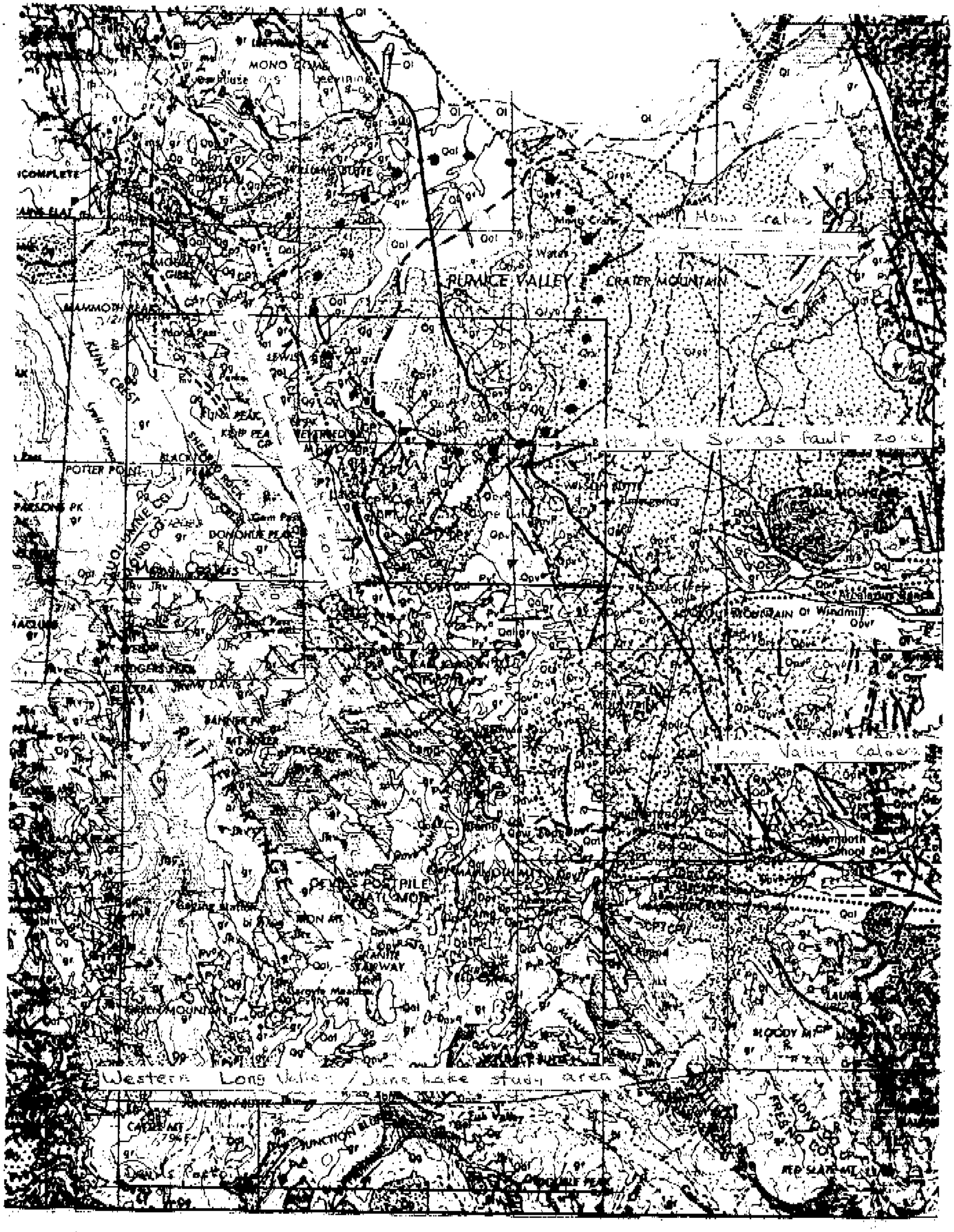

Figure 1 (to FER-157). Location of faults in the Western Long Valley/ June Lake study area. Base map from Strand (1967), scale 1:250,000.